Remote drive condition monitoring

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*This paper appears in:* Cement Industry Technical Conference, 1999. Conference Record. 1999 IEE
On page(s): 31 - 48
11-15 April 1999
Roanoke, VA, USA
1999
ISBN: 0-7803-5523-7
IEEE Catalog Number: 99CH36335
Number of Pages: 429
References Cited: 0
INSPEC Accession Number: 6306724

Abstract:
Remote diagnosis is in use frequently and successfully today. The basis for its successful use is the av
today's level of communication technology and the diagnosable behavior in width and the penetration
motor drive systems. The main use nowadays of the point to point remote diagnostic and the noninteg
monitoring system will be substituted by the fully integrated monitoring system operated via the Intern

Index Terms:
motor drives; machine testing; computerised monitoring; telemetry; remote motor drive condition mon
remote fault diagnosis; communication technology; penetration depth; integrated monitoring system; I

# Remote Drive Condition Monitoring

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**ABSTRACT**

The ongoing globalization in the cement market requires from the cement producer more competitive prices for the product cement. One considerable price component of the product cement is the maintenance cost for the equipment and the down time of the production in case of a failure.
But also on the mechanical and electrical supplier side the globalization is ongoing. The goal of the suppliers is no longe restricted to meeting customers expectation in delivering good quality products but more and more in fulfilling the cement producers essential target to keep their production downtime as low as possible. The reaction time of the equipment supplier, whenever help is needed by the customer, is expected to be as fast as possible and even immediate help is expected.
Taking this important aspect into consideration, the equipment suppliers have reacted immediately. However reaction is and was only possible with the development of modern and fast communication technology. Only this modern communication technology forms the basis for the customer's problem solving process requirement.

The modern communication technology asks for new structures in the cooperation relationship between the Customer and the Suppliers, Local or regional technology support centers. A responsibility sharing between service activities on the lower end and the higher end of technical complexity and expertise is envisaged. Local representatives are mainly responsible for the lower end of the service meanwhile the main service centers is responsible for the higher end of the technical complexity. The main service center possesses the so important critical mass of know-how and technological expertise. The remote diagnostic engineers, who have this kind of technological expertise and make use of today's available information technology, will provide the technical support for the customers.

The Remote Diagnostic Engineer for variable speed drives is usually situated a long distance from the drive itself. Nowadays if a problem arises in the drive system the client can request remote technical assistance. Consequently, the engineer does not need to travel a long way to site as this entails a great deal of time and expense. Analyzing the drive performance and making appropriate parameter changes or recommendations on a remote basis can solve the problem. This can be done without an engineer being on site by utilizing the communication port of the drive and the telephone network. This paper describes the requirements for such a system, as well as an application case study describing the effectiveness of the system.

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## 1. REMOTE DIAGNOSTIC

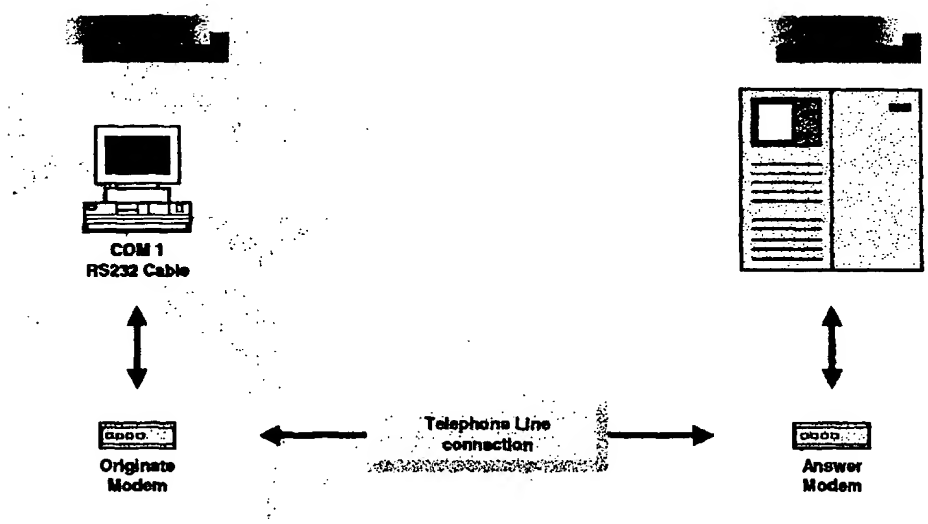
*Support – Functions*

Support functions for Adjustable Speed Drives are, in fact, equipment supplier oriented and not standardized at all. The functions for the Remote Diagnostic - the Application Software for testing purposes for Hardware and Software inside of an Adjustable Speed Drive - are dependent on the programming and the operating system used.
The Download and Upload functions, the remote diagnostic functions and the monitoring are largely dependent on the Hardware structure and the basic firmware. Therefore the Supplier Support functions will be developed and offered independently. The Support functions from one supplier to another supplier of Adjustable Speed Drive Systems are not compatible but this is based on the way support functions are used today but this is not a limiting factor.
Tendencially the control and operating systems are moving toward open control systems. Latest when this tendency will become best practice, the support functions as well will have to be standardized.
This paper will not describe the communication way via telephone line or terrestrial communication but will focus on the accessibility to the drive system and the remote support possibilities.

### 1.1. Possible Remote Modem Configuration

#### *1.1.1. Supplier PC to Modem ↔ Customer Modem to Drive*

In the simple way to carry out remote diagnostic, the remote diagnostic connection is realized from the Supplier PC via the modem and the public telephone network to the customer modem and from that directly to the drive.

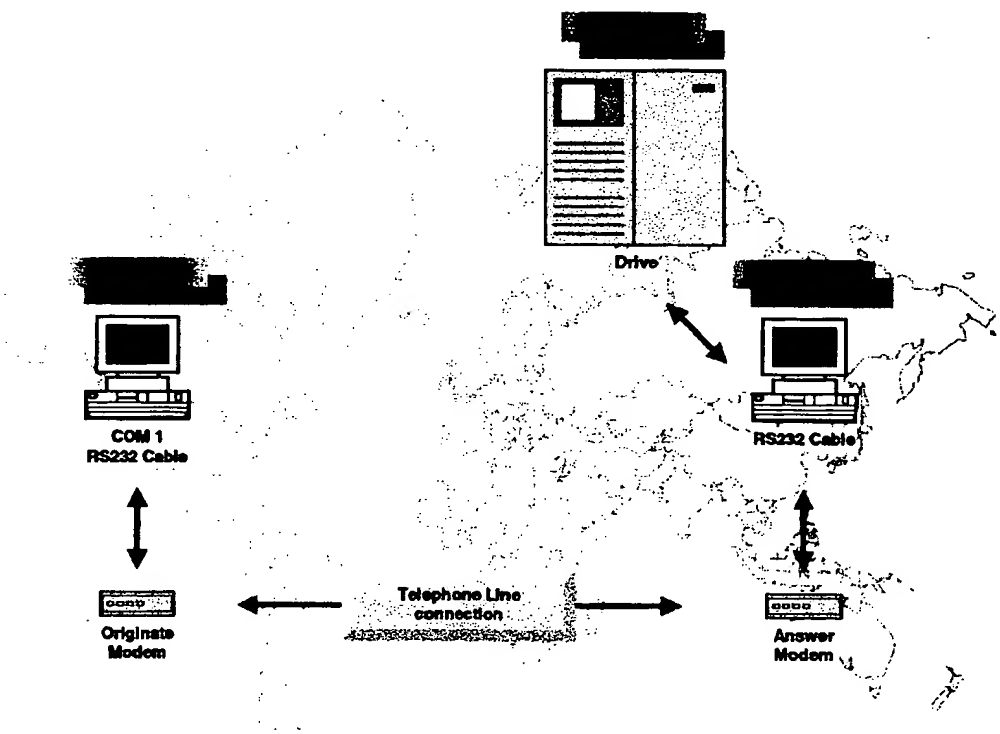



*Picture 1. shows Modem Configuration*
*Supplier PC to Modem ↔ Customer Modem to Drive*

| PROS | CONS |
|---|---|
| • Does not need a PC at the drive. This saves money, and means less components that can be faulty. | • Cannot access the drive locally, unless the modem link is removed and a PC is connected to the drive. |
| • The customer has no possibility of using the PC as it must be available when its needed. | • Not much flexibility. Can only be connected to one device at a time. |
| • Simple Physical layout – just an extra Modem. Can easily be built into existing cabinet. | • To perform trending, you need to be connected to the remote site for the duration of the trend. Can lead to expensive phone bills. |
| • Easy to commission. Pre-program modem and simply switch on. | • Cannot easily connect additional probes, etc. Additional multiplexers or manual assistance needed. |
| | • Modem requires non-standard settings and limited to the baud rate of 4800 baud |
| | • Very slow |

### *1.1.2. Supplier PC- Modem ↔ Customer Modem - PC ↔ Drive*

In the standard way to carry out remote diagnostic, the remote diagnostic connection is realized from the Supplier PC via the modem and the public telephone network to the customer modem and from that directly to the Customer PC and from there to the drive.

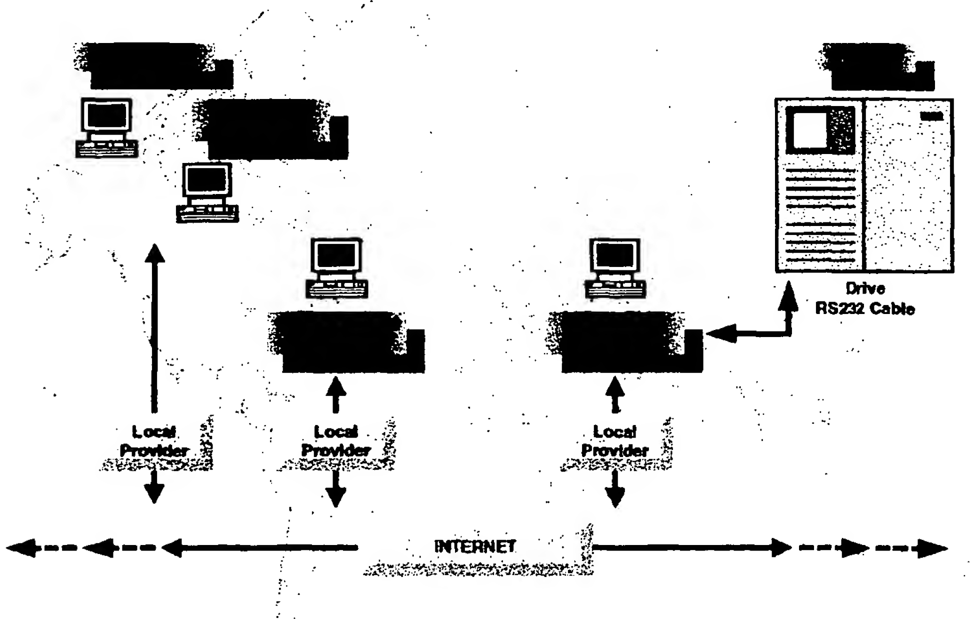



*Picture 2. shows Modem configuration*
*Supplier PC-Modem ↔ Customer Modem-PC ↔ Drive*

| PROS | CONS |
| --- | --- |
| • No special settings required for modems. | • More components |
| • When trending, does not have to be connected the whole time. Data file can simply be downloaded. | • PC required. Can be tampered with. Industrial PC required - expensive; which also needs to be installed in some type of cabinet. |
| • Can be expanded to include other devices on a common bus. | • Power needs to be supplied to PC |
| • PC available for local evaluation of drive system for the client and Supplier | • Extra work required during commissioning to setup PC. |
| • Speed of modem unrestricted. Can run at 28800 baud. | • Speed slow when dealing with certain graphic interfaces |
| • As a fallback, it would be possible to connect directly to drive if the modems allow it and someone at the drive side changes the connections (easy). | • Program & data needs to be transmitted - slows process, although compensated by faster modems. Still much faster than the direct connection as shown in picture 1. |

### *1.1.3. Remote PC- ↔ Internet ↔ Customer PC ↔ Drive*

In the sophisticated and future way to carry out remote diagnostic, the remote diagnostic connection is realized from the Supplier PC via a local provider to the Internet, and from the Internet via a local provider to the Customer PC and from there to the drive.




*Picture 3. shows the remote diagnostic configuration via the Internet*

| PROS | CONS |
| --- | --- |
| • Remote diagnose will be realized with standard Function modules which are commonly used in the Internet Programming | • Decentralized intelligence and data storage on customer side is absolutely necessary |
| • When trending, do not have to be connected the whole time. Data file can simply be downloaded. | • No on-line diagnosis possible |
| • Can be expanded to include other devices and other users, no point to point connection. | |

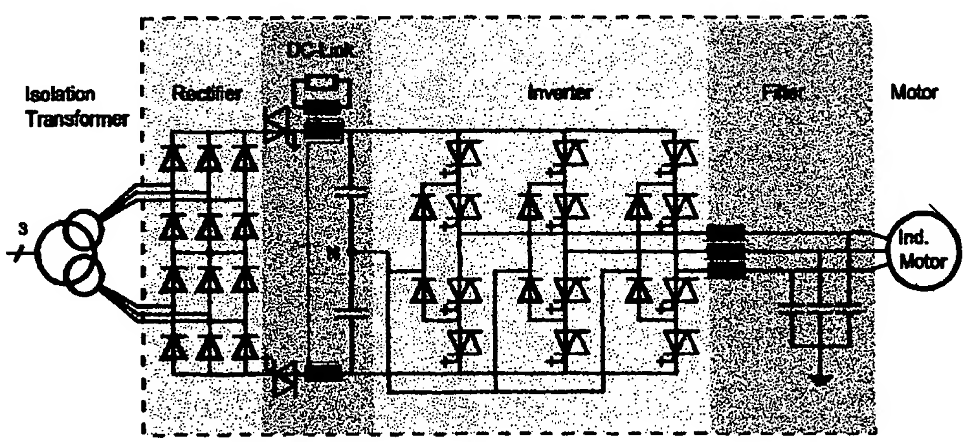
## 2. QUALITY OF A DIAGNOSTIC SYSTEM

The quality of a diagnostic system is generally defined with the capability of horizontal and vertical information penetration into the drive system.

The wider and the deeper the information penetration can be realized, the better the result in precisely reflecting the status or the fault of a given situation:

- In sophisticated diagnostic systems, the status or the fault is clearly reflected
- In poor diagnostic systems the status or the fault can only be predicted with a combinatory logic assumption.

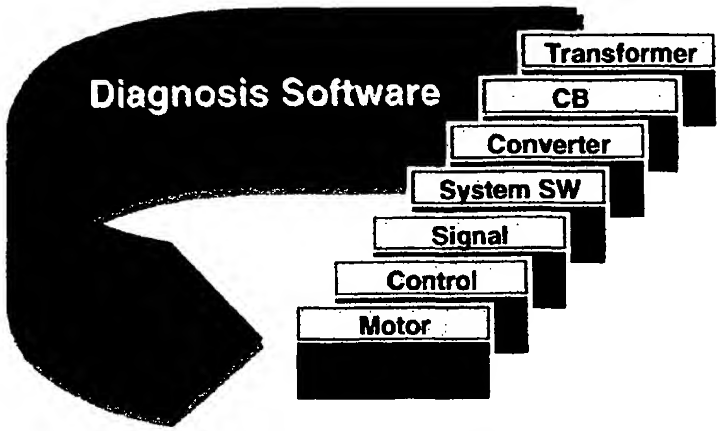
The picture 4 shows a simplified electrical diagram of a drive system comprising of most of the elements. The quality of the diagnostic system is its capability to communicate which each element involved and detect any malfunctions.




*Picture 4. shows a simplified electrical diagram of a drive system*

## 3. BREADTH OF DIAGNOSTIC

*Breadth of diagnostic* is best described as the ability of the diagnostic system in breadth. This means the diagnostic ability spread over all the components of an Adjustable Speed Drive (ASD), beginning from the MV breaker, the transformer, to the drive itself with its rectifier, the DC Intermediate link, the Inverter with all the IGCTs and the output filter, and ending with the motor.



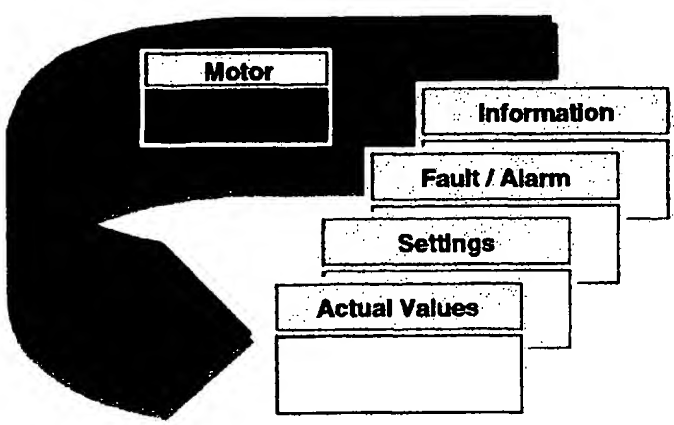

*Picture 5. shows the diagnostic band in width*

## 4. DEPTH OF DIAGNOSTIC

*Depth of diagnostic* is best described in the ability of the diagnostic system in the grade of penetration of the information available for the part of the Software as well as for the part of the Hardware.

### 4.1. First penetration level

The diagnostic band in depth at the first penetration level is structured in actual values, settings, fault/alarms and information. Each of the components in the ASD like motor, transformer etc is structured the same way.

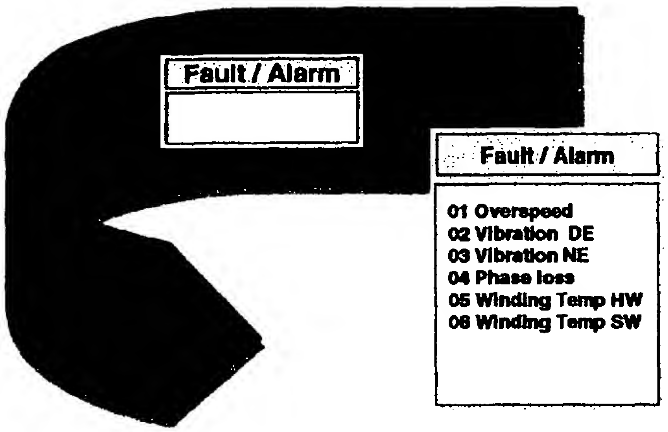



*Picture 6.*

*shows the first penetration level of the diagnostic band in depth*

### 4.2. Second penetration level

The diagnostic band in depth at the second penetration level is structured more detailed, like for the fault/alarms from the motor for overspeed, vibration on DRIVE END, vibration on NON DRIVE END, phase loss etc.



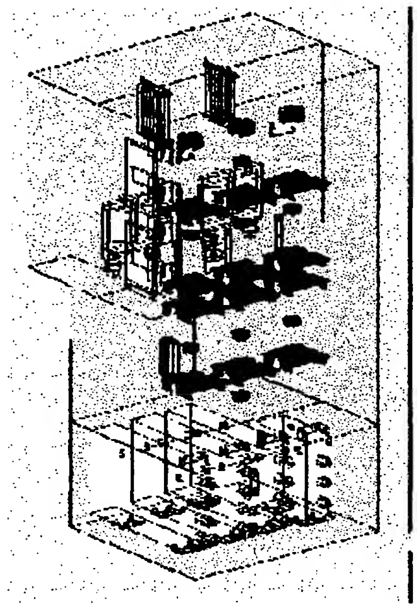

*Picture 7.*

*shows the second penetration level of the diagnostic band in dept*

## 5. BEST PRACTICE WITH REMOTE DIAGNOSTIC

For the best practice in remote diagnostic nowadays, will be used the second example of remote modem configurations as it is shown in picture 2. Namely the communication from Supplier PC to modem via public network to the customer modem, and the customer PC to the drive itself. First of all if a problem in the drive system occurs the customer's maintenance personel will try to resolve the problem by themselves.
Once the problem is identified, for instance the remote diagnose indicates the failure of a hardware part in the drive, this hardware part has to be changed. The supplier remotely sends the procedure in a written and pictured form by E Mail to the client.
The Drive Support Tool show all activities to be done in order to check, dismantle, change and remount an electronic board, fuse, IGCT or Thyristor.

The customer follows these instructions step by step as shown on the received information.



*With this information the part to be changed will be identified.*

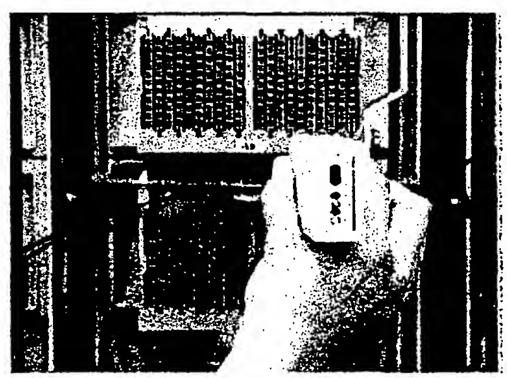
*Picture* 8. *shows the physical disposition of the elements. The faulty one is indicated*

Once the IGCT is identified, the procedure for changing of the IGCT will be transmitted via the remote connection from the supplier. The pictures are numbered in the sequence of the changing procedure and the steps to be done are described.

In this case the next step will be shown with the picture 9. This step describes how the damage to the IGCT can be verified. The verification can be done with an IGCT tester.

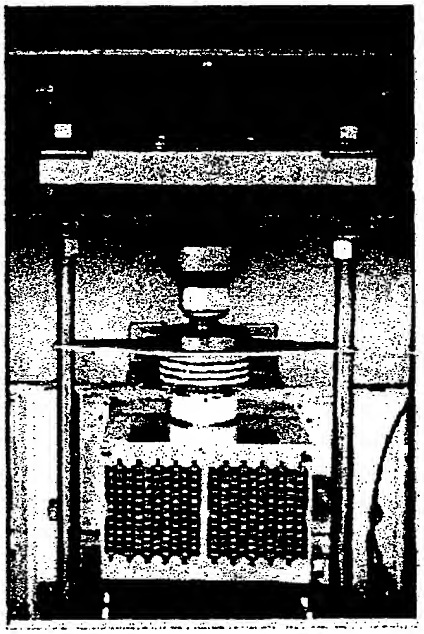
*This test verifies the IGCT is really defective. All these activities are to be carried out with the drive disconnected and isolated from the network, thus complying with the safety standards.*

*Picture 9.* *shows how damage of the IGCTs can be verified with an IGCT tester*



Once the damaged IGCT is proven to be defective with the IGCT tester the next step, to dismantle the IGCT, can be started. This procedure is again described in detail with the picture 10.

The description can be as follows:

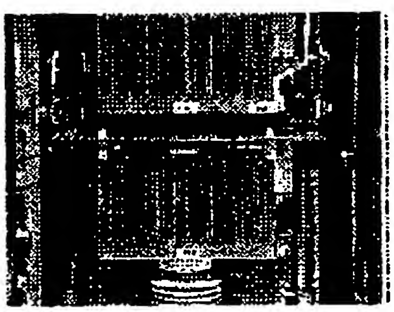


*Release the pressure spring by opening the 24 mm nuts on the stack top. Loosen each nut with the wrench a half turn at a time until you can loosen both nuts with your fingers. To indicate which nut has to be loosened, these nuts are indicated on the picture with red squares.*

*Picture* 10. *shows and describes how to dismantle the IGCT*

After step 10 is carried out, step 11 describes how to continue with the activity of changing the IGCT.

The detailed description advises the following:



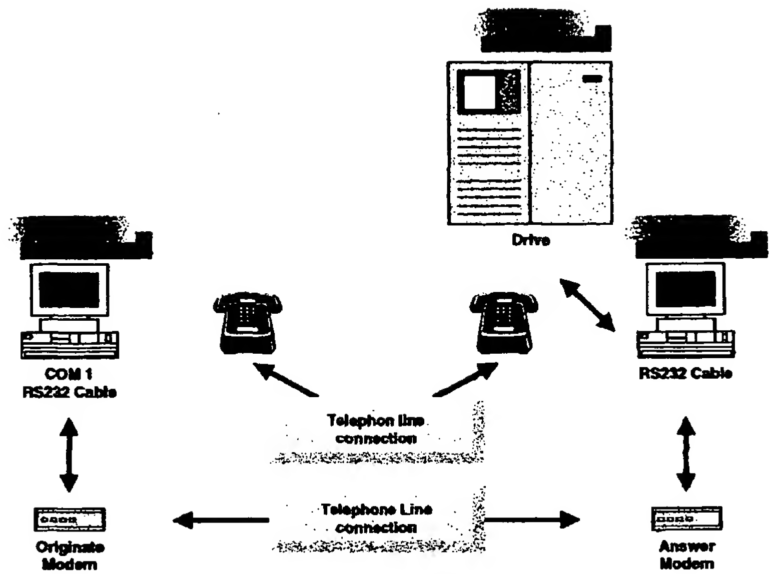
*Unplug the fiber optic cable and power supply connector marked with red squares. Place the lifting tools on both sides of the heat sink above the faulty IGCT. Fix the tool on the iron bar by tightening the lower bolt marked in green with a 10mm wrench.*

*Picture* 11. *shows how to proceed with the activity*

The changing of the IGCT is further described with more pictures.

If the Customer is not able to identify the problem in a reasonable time, he can call the supplier of the equipment. The Supplier connects the remote diagnostic tool to the Customers drive system.

An indispensable help is the installation of a second telephone line parallel to the remote diagnostic line. In this configuration the Supplier having connection via the remote diagnostic to the drive will be supported and assisted by the Customer's engineer. With teamwork the remote diagnostic can started.




*Picture* 12. *shows the actual method for the remote diagnostic*

The customers PC will be set as the slave. No operation from this PC is now possible. The customers PC will be operated from the Supplier side. The Customer's engineer can participate as follows:

- Telephone dialogue with the Supplier's support engineer.
- He can follow the steps on the PC screen. The Supplier's PC will show exactly the same information as that shown on the Customer PC.

**DIFFERENT KIND OF DIAGNOSTICS**

*A* *Diagnostic on a running drive – condition monitoring*
For this kind of diagnostic, mainly the actual drive data will be compared with the fingerprints of the drive data made during commissioning or a previous service activity. The comparison with the fingerprint indicates the condition of the drive or the change of its original behavior. This kind of monitoring is mainly a preventive maintenance activity.

*B* *Diagnostic with intermittent failures on the drive*
This kind of diagnostic will be realized when the drive itself is running, but from time to time non-reproducible intermittent failures occur which lead to not programmed disconnection of the drive.

*C* *Diagnostic on a stopped drive due to a removable failure*
This kind of diagnostic will be applied when the drive already has been disconnected due to a failure in the drive system. The drive cannot restart again. Typical failure for this is a hardware failure.

For all these three different diagnostics purposes, there is huge amount of diagnostic tools available in order to recognize the problem, isolate the failure and define the reason for the failure. The following

chapter describes these tools. The more these tools are available, the better and faster the failure can be traced and found.

# 6. DIAGNOSTIC TOOLS

## 6.1. Monitoring tool

The Monitoring Tool is used for trending the actual values of the target device and the following is possible:

- Zoom in and Zoom out
- Scaling the Graphs
- Setting the Sampling Interval
- Setting the length of the visible screen
  Triggering on specific conditions

## 6.2. Signal and Parameter tools

With this tool all the available signals and parameters can be observed and checked.

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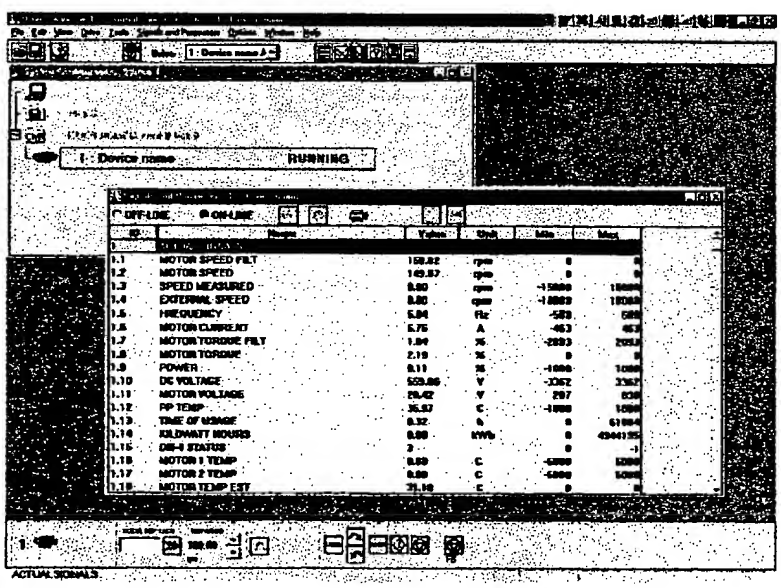


*The operation mode can be set in the online mode. In this mode all the signals will be shown with their actual values.*

*Picture* 13. *shows the signal and parameter tool*

## 6.3. Data logger

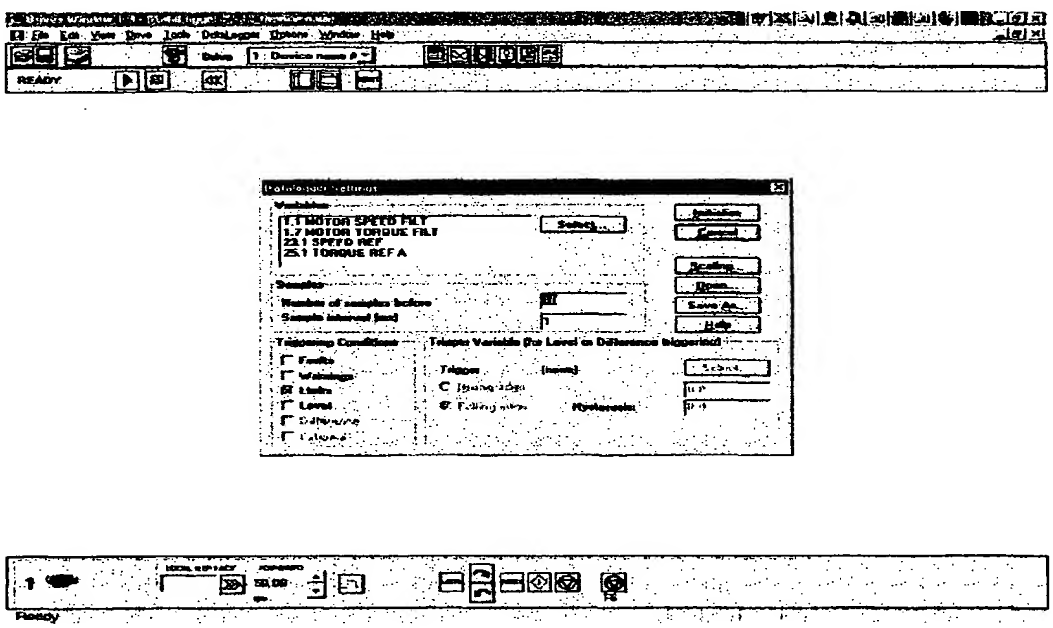
The Data Logger Tool is used for controlling the Data Logger of the Drive and for displaying their content in graphical or numerical mode. Setting the Data Logger is possible with any variable. Up to four different

variables can be set on the Logger and each one of them could be used as a trigger with a selectable trigger level. The Trigger signal for starting or stopping the Logger could be when:

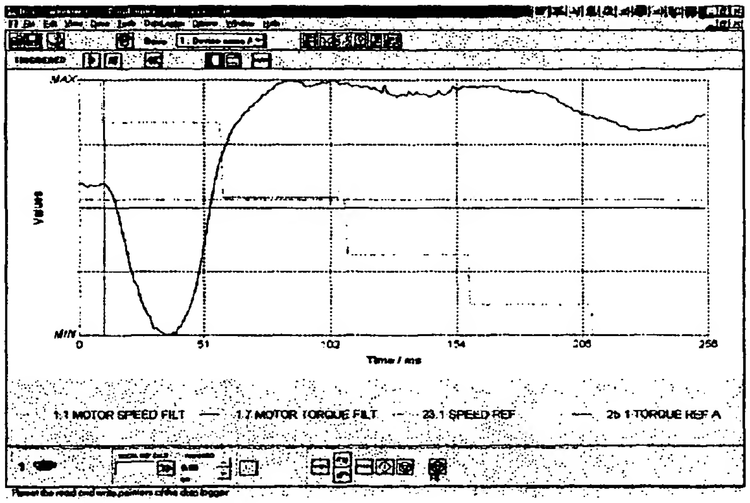
- Faults occur
- Warnings occur
- Limits are reached
- Levels, hysteresis and falling or rising edge of the variables are reached

Trigger signals are used for starting or stopping an action. The trigger can be set in the transient recorder. In this mode the selected variable can be observed before and after the trigger has occurred.

For example the trip signal can be used to trigger the logger and then the other variables checked before and after the trigger to see what influence they had on the fault.




*Picture 14. shows selected Variables in the Datalogger setting box. The Variables can be taken out of a Variable box containing all Variables.*



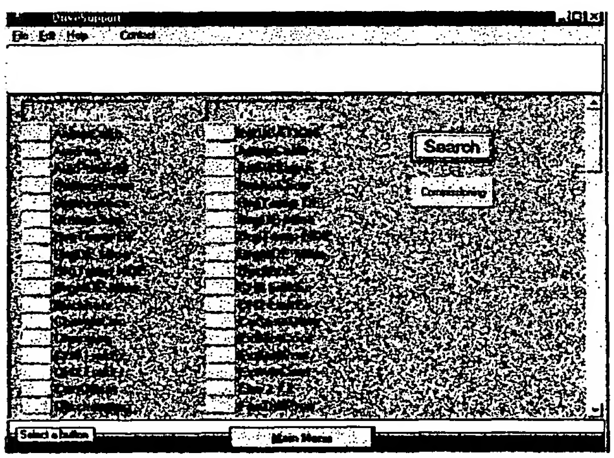

*Picture* 15. *shows a reading with the datalogger tool*

### 6.4. Event logger

The Event Logger Tool is used when a recording of all events should be done. This Tool is very helpful in the fault tracing procedure. This tool will mainly be used on intermittent and unpredictable fault.

### 6.5. Fault logger

The Fault Logger Tool is used for displaying the contents of the fault logger buffer. The fault logger includes information of a number of most recent faults and warnings in the drive in chronological sequence and with a time mark.




*Picture* 16. *shows the Fault logger tool*

### 6.6. Application tool

The Application Tool is used for:

- Downloading and uploading programs
- Debugging application programs.

The application tool shows and lists as well the

- Version of the application program saved.
- Version of the current application program.
- System Software information
- Function Block library.

## 7. DIAGNOSTIC CASES

Remote Diagnostic is a tool to serve customers faster, better and with lower costs but is only at the beginning of the development for its intended use.

In most cases Customers try to solve their own problems. There are no statistics which show the average meantime to repair. The Supplier will normally be called in when the problem cannot be solved in a certain time frame.
There is also the fact that the older equipment is not easily diagnosable. Newer equipment, which has diagnostic facilities, seldom fails. The system diagnosis is still in its infant stage and therefore no statistics are available.
In those cases were the Supplier is asked to solve the problem remotely, help could be provided. Classical cases from experience are when, after a time in operation, the drive system has failed and by using the data logger, event logger and fault logger tool help could be given in most cases.

Other cases are when customers are not sure whether the problem source is initiated from mechanical or the electrical side. In these cases the drive system can be verified remotely if it is functioning correctly and where the source of the problem is to be found. For these purposes the hit rate is quiet high.

## 8. REMOTE DIAGNOSTIC COSTS

The prediction of the remote diagnostic costs itself are not too difficult because the costs are visible. However the comparison of remote diagnostic costs versus direct service of the drive system has many variables. The variables are distance from the next service organization to the customer, availability of flights, etc. To consider all these variables too many assumptions have to be made and therefore comparisons become realistic only for one case. Today, based on experience with known cases, the assumption can be made that resolving a problem with the remote diagnostic costs only about 20% of the costs from a direct service. It is most likely even much more cost significant when taking into account the downtime of the plant and the related production losses.

### 8.1. A summary of the Remote Diagnostic costs is shown

*Supplier*

- Time for Expert Remote Diagnostic Support

*Customer*

- Verbal communication Telephone line Costs
- Remote diagnostic telephone line Costs
- Installation of a PC for this purpose
- Installation of a audio Telephone line from the drive to the telephone network
- Installation of a Remote diagnostic telephone line from the drive to the telephone network

## 8.2. Advantages of Remote Diagnostic

- Reaction time is immediate
- Down time of the drive is shorter, resulting in reduced production losses.
- No travel costs for drive system experts
- Site expertise can be reduced to a certain level and thereby costs saved
- The drive is immediately available after a successful diagnostic
- Drive diagnostic can be used for preventive maintenance.

# 9. DIAGNOSTIC HIT RATE

For the Remote Diagnostic hit rate only empiric results are available. As expressed already, under normal conditions the Client tries to resolve the problem himself first. Only if the customer cannot resolve the problem in due time will he call the assistance of a remote diagnostic support. Therefore it can be assumed that only the more difficult problems will be transferred to and known by the Supplier.

There are already customers who have made a contract with the supplier to completely service their plant because of the availability of a remote diagnostic system. In these cases, the customer immediately contacts the supplier if a problem arises.

From the empiric point of view it can be stated that the hit rate was better than 60% when help with the remote diagnostic tool was given.

# 10. SYSTEM DIAGNOSTIC

## 10.1. Concept for Inclusion of Total Rotating System Condition Monitoring

Although the Drive Monitoring program offers a great deal of information regarding the condition of the electronic drive system, it only provides limited information on the motor and mechanical system of the drive.

The most important parameters that need to be monitored to assist the engineer in fault tracing are vibration, current and temperature measurements. It is possible to analyze the motor current using the Monitoring program and up to a certain extent a detailed FFT spectrum analysis is possible. In this section, two concepts will be given to allow for the extended remote monitoring capabilities. The first concept is relatively simple but far less flexible than the second concept, which will require a lot of time investment to get it in an operational state.

## 10.2. Non-Integrated Monitoring System

In this form of monitoring system, no communication exists between the different monitoring systems and only one system can be accessed at a time. Separate monitoring units are thus used, with no attempt being made to try and integrate them with one another. Here it would be possible to have a connection via PC to the site being monitored.
A typical case for applying this type of monitoring to a machine would run as follows:

- The modem would first be connected via PC to the Drives Panel
- A connection would then be established and all the relevant parameters checked/changed in the drive.
- If more information e.g. vibration of the motor is required, the connection to the drive could now be terminated and the client would attach the connection to the vibration measurement